CLAIMS

1. An ultrasonic diagnosis system comprising:

an ultrasonic probe for performing transmission/reception of ultrasonic signals to/from a subject;

storage means for storing the properties of signals detected with said ultrasonic probe;

correlation computing means for calculating the correlation coefficient between said properties with and without pressure applied to the subject, and the phase difference between said received signals with and without application of pressure, based upon said properties stored in said storage means with and without pressure applied to said subject;

computing means for calculating the displacement of each measurement point, and the strain distribution of the tissue of said subject due to said application of pressure, based upon said correlation coefficient and said phase difference calculated by said correlation computing means; and

display means for displaying said strain distribution.

2. An ultrasonic diagnosis system according to Claim 1, wherein said properties comprise a parameter which represents correlation between the wave properties such as

envelope signals, the amplitude, the wave height, and the wave number.

3. An ultrasonic diagnosis system according to Claim 1, wherein said correlation computing means set measurement points on ultrasonic beam data formed of envelope signals detected with said ultrasonic probe with and without pressure applied to said subject, said envelope signals being stored in said storage means; and wherein the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure is detected by varying said measurement points at least in the ultrasonic beam direction, as well as calculating the phase difference between said received signals with and without application of pressure;

and wherein said computing means include displacement computing means for calculating the displacement of each measurement point due to said application of pressure based upon the position which exhibits said maximum correlation coefficient and said phase difference calculated by said correlation computing means.

4. An ultrasonic diagnosis system according to Claim 3, wherein said computing means include strain computing means for calculating the strain distribution of the tissue of said subject by performing spatial differentiation of the

displacement of said measurement points.

5. An ultrasonic diagnosis system according to Claim 3, wherein said correlation computing means detect the position which exhibits the maximum correlation coefficient by varying said measurement points in said ultrasonic beam direction at a pitch half the wavelength of said ultrasonic signals.

6. An ultrasonic diagnosis system according to Claim 3, wherein said correlation computing means calculate autocorrelation functions for said envelope signals under pressure, and correlation coefficient is calculated between said autocorrelation functions by varying the phase between said autocorrelation functions at a pitch half the wavelength of said ultrasonic signals corresponding to said variation of said measurement points, thereby obtaining the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure.

7. An ultrasonic diagnosis system according to Claim 6, further comprising elastic modulus computing means for creating at least a two-dimensional finite element model by dividing said subject into a finite number of elements, computing the elastic modulus distribution based upon the information which is used for creating said model and said strain distribution, and displaying said elastic modulus

distribution with said display means.

8. An ultrasonic diagnosis system according to Claim 1, wherein said correlation computing means set measurement points on frame data of said envelope signals with and without pressure applied to said subject; said frame data serving as slice data being stored in said storage means, and detect the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure by varying a two-dimensional correlation window at least in two-dimensional directions as to said frame data; said two-dimensional correlation window surrounding said measurement points which are to be used for correlation, as well as calculating the phase difference between said RF signals with and without application of pressure;

and wherein said computing means include displacement computing means for calculating at least the two-dimensional displacement of each measurement point due to said application of pressure based upon said position of each measurement point which exhibits said maximum correlation coefficient and said phase difference calculated by said correlation computing means.

9. An ultrasonic diagnosis system according to Claim 8, wherein said two-dimensional directions comprise the ultrasonic-beam direction where said ultrasonic probe

receives said ultrasonic beam, and the ultrasonic-beam scanning direction.

10. An ultrasonic diagnosis system according to Claim 9, wherein said correlation computing means detect the position of each measurement point which exhibits the maximum correlation by varying said measurement points in said ultrasonic-beam direction at a pitch half the wavelength of said ultrasonic wave signals, and in said ultrasonic-beam scanning direction at said ultrasonic-beam pitch.

11. An ultrasonic diagnosis system according to Claim 8, further comprising elastic modulus computing means for: creating at least a two-dimensional finite element model by dividing said subject into a finite number of elements; computing the elastic modulus distribution based upon the information which is used for creating said model; and said strain distribution; and displaying said elastic modulus distribution with said display means.

12. An ultrasonic diagnosis system according to Claim 8, wherein said correlation computing means detect the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure for said measurement points surrounded by said two-dimensional correlation window by varying the phase of the autocorrelation function of said envelope signals under pressure corresponding to said

variation of said measurement points.

13. An ultrasonic diagnosis system according to Claim 5, wherein frame data stored in said storage means comprises volume data formed of a plurality of slice frame data sets, and wherein said correlation computing means detect the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure for said measurement points surrounded by a three-dimensional correlation window by varying said measurement points surrounded by said three-dimensional correlation window as to said volume data in the three-dimensional directions, as well as calculating the phase difference between said RF signals with and without application of pressure.

14. An ultrasonic diagnosis system according to Claim 13, wherein said three-dimensional directions comprise the ultrasonic-beam direction where said ultrasonic probe receives said ultrasonic beam, the ultrasonic-beam scanning direction, and the slice direction orthogonal to said two directions.

15. An ultrasonic diagnosis system according to Claim 14, wherein said correlation computing means detect the position of each measurement point which exhibits the maximum correlation by varying said measurement points in said ultrasonic-beam direction at a pitch half the wavelength of

said ultrasonic wave signals, in said ultrasonic-beam scanning direction at said ultrasonic-beam pitch, and in said slice direction at the slice pitch of said ultrasonic beam.

16. An ultrasonic diagnosis system according to Claim 13, wherein said correlation computing means calculate the phase difference between said RF signals with and without said application of pressure in said ultrasonic-beam direction, in said ultrasonic-beam scanning direction, and in said slice direction orthogonal to said two directions.

17. An ultrasonic diagnosis system according to Claim 13, further comprising elastic modulus computing means for creating at least a three-dimensional finite element model by dividing said subject into a finite number of elements, computing the elastic modulus distribution based upon the information which is used for creating said model and said strain distribution, and displaying said elastic modulus distribution with said display means.

18. An ultrasonic diagnosis system according to Claim 13, wherein said correlation computing means detect the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure for said measurement points surrounded by said three-dimensional correlation window by varying the phase of the autocorrelation function

of said envelope signals under pressure corresponding to said variation of said measurement points.

19. An ultrasonic diagnosis system according to Claim 17, wherein said elastic modulus computing means create a three-dimensional finite element model by dividing the tissue of said subject into a finite number of rectangular parallelepiped elements on the assumption that the tissue of said subject exhibits isotropic elasticity and near-incompressibility, and compute the elastic modulus distribution based upon said strain distribution using the elastic equation on the assumption that each element exhibits the uniform elastic modulus, the uniform stress, and the uniform strain.

20. A strain distribution display method wherein the displacement of the tissue of the subject is calculated based upon the signals obtained by measurement with an ultrasonic probe with and without pressure applied to the tissue of said subject, the strain distribution of the tissue of said subject is calculated based upon said calculated displacement, and said strain distribution is displayed with display means, said method comprising:

a first step for calculating the properties of said signals received with and without application of pressure;

a second step for calculating the correlation coefficient between said properties with and without said

application of pressure and the phase difference between said signals with and without said application of pressure based upon said properties;

a third step for calculating the displacement of each measurement point due to said application of pressure and the strain distribution of the tissue of said subject based upon said correlation coefficient and said phase difference thus obtained; and

a fourth step for displaying said obtained strain distribution with said display means.

21. A strain distribution display method according to Claim 20, wherein said properties comprise a parameter which represents correlation between the wave properties such as envelope signals, the amplitude, the wave height, and the wave number.

22. A strain distribution display method according to Claim 20, wherein in said second step, measurement points are set on said stored ultrasonic beam data formed of envelope signals detected with said ultrasonic probe with and without pressure applied to said subject,

and wherein the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure is detected by varying said measurement points at least in the ultrasonic beam direction, as well as

calculating the phase difference between said received signals with and without application of pressure,

and wherein in said third step, the displacement of each measurement point due to said application of pressure is calculated based upon the position which exhibits said maximum correlation coefficient and said phase difference thus calculated.

23. A strain distribution display method according to Claim 22, wherein said third step includes strain computing means for calculating the strain distribution of the tissue of said subject by performing spatial differentiation of the displacement of said measurement points.

24. A strain distribution display method according to Claim 22, wherein in said second step, the position which exhibits the maximum correlation coefficient is detected by varying said measurement points in said ultrasonic beam direction at a pitch half the wavelength of said ultrasonic signals.

25. A strain distribution display method according to Claim 22, wherein in said second step, autocorrelation functions for said envelope signals under pressure are calculated, and correlation coefficient is calculated between said autocorrelation functions by varying the phase between said autocorrelation functions at a pitch half the wavelength of said ultrasonic signals corresponding to said

variation of said measurement points, thereby obtaining the position of each measurement point which exhibits the maximum correlation coefficient between said envelope signals with and without application of pressure.

26. A strain distribution display method according to Claim 20, wherein in said second step, measurement points are set on frame data of said envelope signals with and without pressure applied to said subject; said frame data serving as slice data, and the position of each measurement point is detected so as to exhibit the maximum correlation coefficient between said envelope signals with and without application of pressure by varying a two-dimensional correlation window at least in two-dimensional directions as to said frame data; said two-dimensional correlation window surrounding said measurement points which are to be used for correlation, as well as calculating the phase difference between said RF signals with and without application of pressure,

and wherein in said third step, the displacement of each measurement point due to said application of pressure is calculated in at least two-dimensional displacement based upon said position of each measurement point which exhibits said maximum correlation coefficient and said phase difference thus calculated.

27. A strain distribution display method according to

Claim 26, wherein said two-dimensional directions comprise the ultrasonic-beam direction where said ultrasonic probe receives said ultrasonic beam, and the ultrasonic-beam scanning direction.

28. A strain distribution display method according to Claim 27, wherein in said second step, the position of each measurement point is detected so as to exhibit the maximum correlation coefficient by varying said measurement points in said ultrasonic-beam direction at a pitch half the wavelength of said ultrasonic wave signals, and in said ultrasonic-beam scanning direction at said ultrasonic-beam pitch.

29. A strain distribution display method according to Claim 26, wherein in said second step, the position of each measurement point is detected so as to exhibit the maximum correlation coefficient between said envelope signals with and without application of pressure for said measurement points surrounded by said two-dimensional correlation window by varying the phase of the autocorrelation function of said envelope signals under pressure corresponding to said variation of said measurement points.

30. A strain distribution display method according to Claim 20, wherein in said second step, measurement points are set on volume data of said envelope signals with and without application of pressure; said volume data

corresponding to a plurality of slice data sets for said subject, and the position of each measurement point is detected so as to exhibit the maximum correlation coefficient between said envelope signals with and without application of pressure for said measurement points surrounded by a three-dimensional correlation window by varying said measurement points surrounded by said three-dimensional correlation window in the three-dimensional directions as to said volume data, as well as calculating the phase difference between said RF signals with and without application of pressure;

and wherein in said third step, the displacement of each measurement point due to application of pressure is calculated in the three-dimensional directions based upon the position of each measurement point which exhibits said maximum correlation coefficient and said phase difference thus obtained.

31. A strain distribution display method according to Claim 30, wherein said three-dimensional directions comprise the ultrasonic-beam direction where said ultrasonic probe receives said ultrasonic beam, the ultrasonic-beam scanning direction, and the slice direction orthogonal to said two directions.

32. A strain distribution display method according to Claim 31, wherein in said second step, the position of each

measurement point is detected so as to exhibit the maximum correlation by varying said measurement points in said ultrasonic-beam direction at a pitch half the wavelength of said ultrasonic wave signals, in said ultrasonic-beam scanning direction at said ultrasonic-beam pitch, and in said slice direction at the slice pitch of said ultrasonic beam.

33. A strain distribution display method according to Claim 20, further comprising:

a fifth step for creating at least a two-dimensional finite element model by dividing a simulation model created based upon signals received by measurement of said subject into a finite number of elements, and computing the elastic modulus distribution based upon the information used for creating said model and said strain distribution thus obtained; and

a sixth step for displaying said obtained strain modulus distribution with said display means.

34. A strain distribution display method according to Claim 33, wherein said fifth step includes elastic modulus computing means for creating a three-dimensional finite element model by dividing said subject into a finite number of elements, and computing the elastic modulus distribution based upon the information used for creating said model and said strain distribution;

and wherein said elastic modulus distribution is displayed with said display means.